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6 PROTECTIVE COVERINGS FOR ICE AND SNOW -- AQUEOUS FOAM STUDIES,

10 by N. S. Stehle.

1 October 1964

5 [redacted] NAVAL CIVIL ENGINEERING LAB[redacted]

Port Hueneme, Calif[redacted]

PROTECTIVE COVERINGS FOR ICE AND SNOW — AQUEOUS FOAM STUDIES

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Type B

by

N. S. Stehle

ABSTRACT

Summary deterioration of their surfaces hampers the year-round use of natural ice islands and smooth sea-ice areas in the Arctic Ocean and permanent snow and ice areas in the antarctic. Sawdust has been used by the Navy for protecting compacted-snow areas, but its scarcity and shipping bulk preclude its use in polar regions. In developing a suitable protective covering for ice and snow surfaces in polar regions, laboratory and field studies were conducted on protein-base aqueous foams stabilized with sodium carboxymethyl cellulose, ~~by contract~~ with Onondaga Associates, Inc., of Syracuse, N. Y., and by NCEL.

These foams are not adequate for continued protection of ice and snow surfaces against summer deterioration. They are difficult to generate, will not cure under normal polar conditions, have a short field life, are damaged by traffic, and offer only a slight weight savings over sawdust at a considerable increase in cost. Investigations should continue toward developing a covering for operational areas of ice and snow which protects against deterioration from solar radiation and near-thawing temperatures.

INTRODUCTION

In recent years, natural ice islands (tabular icebergs) in the Arctic Ocean have been used for floating scientific stations; smooth sea ice areas have been used for seasonal scientific observations. Both have been used for limited aircraft operations. The scarcity of natural ice islands and smooth sea ice prohibits their widespread use as platforms for floating stations in the ice-covered Arctic Ocean. At best, those areas which have been occupied were suitable only for pioneer operations without considerable improvement. Ice island topography is usually undulating, and often the surface is further accentuated by summer melting. A natural area of smooth sea ice is usually limited in size, often surrounded by rough pressure ice, and seldom thick enough for extensive use. Summer melting often decreases the ice thickness and reduces the ice strength.

The above-freezing ambient temperatures and high solar radiation found in most polar regions during late spring, summer, and early fall cause rapid deterioration of these ice surfaces, resulting in rough, soft surfaces which greatly hamper or prevent travel and aircraft landings. Buildings become elevated on pedestals of protected ice because of the ablation of the surrounding ice.

The first successful material used by the Navy for the protection of ice and snow surfaces was sawdust. It was used on the compacted-snow parking lot and access road at the Olympic Winter Games, Squaw Valley, California, in 1960. However, sawdust is scarce and has a high shipping bulk; hence, aqueous foams, in which water and air are the main ingredients, were considered as a protective covering. These foams were developed and tested by Onondaga Associates, Inc. of Syracuse, N. Y. and further tested by NCEL. The results are summarized in this report.

BACKGROUND

During the Squaw Valley snow-compaction trials in 1960, sawdust was used to protect the snow from deterioration by solar radiation and warm temperatures. Unprotected compacted snow supported vehicle traffic on warm, sunny days only during the morning; by noon the top 5 to 6 inches became too soft and mushy.[1] After several days of continuous thawing temperatures, it was impassable to traffic even in the early morning. Under the same conditions, a 1/4-inch layer of sawdust over the compacted

snow permitted it to support all-day traffic. In addition, this sawdust layer retarded ablation so that little or no loss occurred, although the surrounding snow ablated 12 inches in a 4-week period. Despite its protective ability, sawdust is not considered a good material for polar use because of its bulk and weight.

Work was continued to develop a suitable protective material for polar use. In 1959-60, an apparently ideal material, a protein-base aqueous foam with stabilizer, was investigated by the Air Force through a contract to Onondaga Associates, Inc.[2] In laboratory tests, this foam protected an ice surface during periods of melt and was easily generated from stabilized foam liquids. It appeared that the best of the stabilized foams, when dried under sunlamps, would last indefinitely. However, once frozen, the foam decayed when thawed.

Support of the aqueous-foam research by Onondaga Associates, Inc. was assumed by the Navy in 1961. In that year, laboratory tests were conducted in Syracuse and in the Climatic Laboratory at Eglin Air Force Base, Florida.[3] This formed the basis for field trials on the foam during the spring of 1962 at Point Barrow, Alaska.[3,4] In the summer of 1963, NCEL conducted field trials on a modified foam generator at Port Hueneme, Calif.[5]

FORMULATION

Aqueous foams are water-soluble foaming agents which have long been used for fire extinguishment. In the protective covering tests on ice and snow, a partially hydrolized protein-base foam liquid, Mearlfoam-5, manufactured by Mearl Corporation, Roselle Park, N. J., was used exclusively as the aqueous foam. Various stabilizers were used with the 6 percent (by volume) solution of foam liquid in water. The stabilizers were screened in small-scale laboratory tests. Foam stabilized with the gelling agent sodium carboxymethyl cellulose (CMC), a cellulose gum solution of varying molecular weight and viscosity, and aluminum acetate, a polyvalent cation which controlled the gelling rate, proved to be the most successful in withstanding freeze-thaw cycles and in protecting the ice from melting.

In general, the foam strength increased as the concentration of the CMC stabilizer was increased. The solutions determined to be the most stable with the least amount of stabilizer of each type of CMC available were 1-3/4 percent CMC-7HP, a high-viscosity, high-molecular-weight CMC; 2 percent CMC-12HP, a medium-viscosity high-molecular-weight CMC; and 3 percent CMC-7LP, a low-viscosity, low-molecular-weight CMC. All of these used 25 percent (based on the percent of CMC) aluminum acetate as the gelling rate control. These are the major formulations used in the tests. All others were eliminated in the initial screening.

GENERATION

After completion of the developmental work on the aqueous foam under the Air Force contract, the conclusions reached by Onondaga Associates included building an improved foam generator and continuing the investigation of aqueous foams.[2] However, continuation of this research by Navy contract was limited to the further development of foams of sufficient stability to protect ice surfaces from melting under polar summer conditions, and to field testing the foams with the equipment developed under the original Air Force contract. A determination of the protective and lasting ability of the foams under field conditions was considered essential prior to further equipment development.[4]

The experimental foam generator (Figure 1) for the laboratory and Point Barrow tests was a Roots-Connersville blower with a closed feed system and compressed air. The foam was ejected into a refining section and then through a flexible hose.[3] This generator performed adequately during the laboratory tests, but during the Point Barrow field tests about 50 percent of the foaming time was lost in adjusting the generator. After completing one test area, the foaming of the other plots was delayed 12 days by a broken blower, which had to be replaced from the continental United States. The Point Barrow tests demonstrated the need for a more rugged foam generator for field testing[4] the CMC-7HP-stabilized foam, the most stable of the foams investigated by Onondaga Associates. It was recommended that the foaming rate be 50 square feet per minute with an expansion ratio[2] from 8:1 to 12:1.

NCEL developed a batch generator (Figure 2) for this purpose.[5] Each batch was mixed in 55-gallon drums immediately prior to foaming. The stabilizer and liquid foam were mixed by recirculation and mechanical agitation. The mixture was foamed with a Penberthy injector with compressed air, a refining section, and a centrifugal pump, all connected in series. The foaming achieved with this arrangement (larger piping, regulated pump speeds, and a centrifugal pump for homogenizing liquid and air) was an improvement over that of Onondaga Associates' generator. The foam was applied through a hose and spreader, but it had to be leveled by hand since it did not emerge in a steady stream.

During preliminary tests of the batch generator, using only unstabilized Mearlfoam, a maximum expansion ratio of 10:1 was achieved. With the addition of CMC-7HP stabilizer, the foam was generated at a rate of 50 square feet per minute, but the expansion ratio was reduced. It varied from 2-1/2:1 to 5-1/2:1; this variation was attributed to difficulty in dissolving the stabilizers. The low expansion ratio was attributed to inadequate generator capacity for such a high-viscosity liquid.

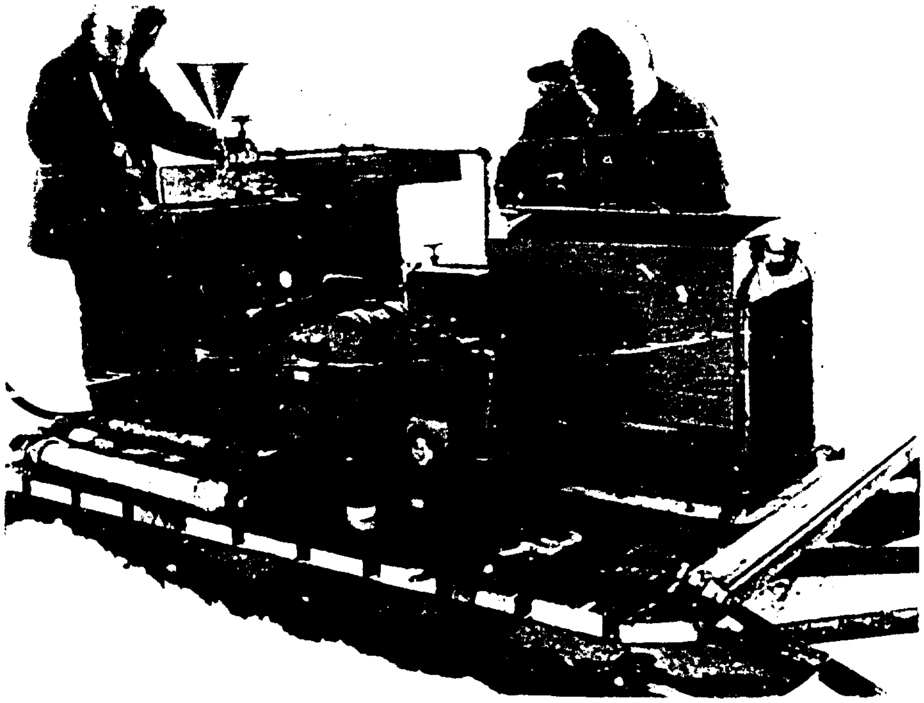

Figure 1. Onondaga Associates' experimental foam generator.

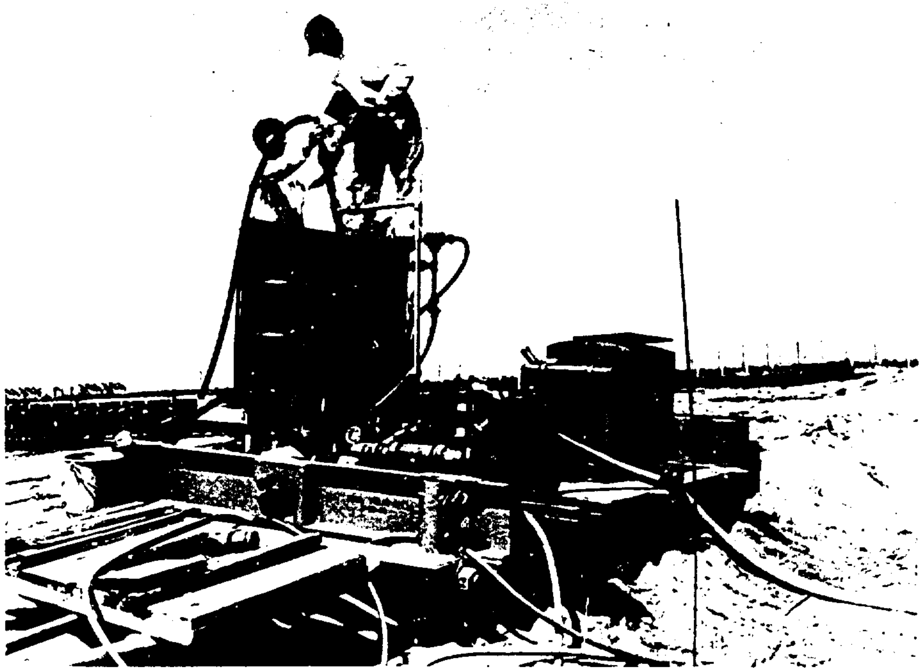

Figure 2. NCEL foam batch generator.

DURABILITY

The laboratory tests in Syracuse, N. Y. were conducted with 500-milliliter ice samples in a home freezer. Foam-protected and unprotected samples were subjected for 24 to 48 hours to sunlamp heat and radiation on one side while the other side was submerged in a freezer maintained at 25 F. Although some of the protected ice melted, it melted more slowly than the unprotected ice. Under the sunlamp, the CMC-stabilized foam became dry and stiff.[3]

The three types of CMC stabilizer were tested in the Climatic Hanger at Eglin Air Force Base. The cold chambers were kept at 25 F. Each foam was placed on a 4-foot by 2-foot by 6-inch pan of ice and subjected to simulated polar radiation from sunlamps. The CMC-7HP-stabilized foam was the strongest, and the CMC-12HP was the weakest. In the high solar radiation and low humidity of the cold chamber, all foam formulations dried to a highly cellular, very lightweight foam. The CMC-12HP and the CMC-7LP had expansion rates of 8.7 and 8.3, respectively, but the expansion ratio of the CMC-7HP was only 6.0, or 1/4 less. The high viscosity of the CMC-7HP prevented easy generation with the available equipment. Because the CMC-7LP appeared adequate for field testing and was easy to generate with the experimental foam generator, it was used in the field tests at Point Barrow, Alaska.[3]

The tests were conducted by Onondaga Associates, Inc.[3,4] between 16 May and 27 June 1962 in an air temperature near 30 F. A 2- to 3-inch thickness of foam was placed on an 800-square-foot area of natural ice nearly 3 weeks before the beginning of thaw (as marked by flooding of the ice surface with melt water). Within 13 days in air temperatures varying from 10 to 43 F, the foam had dried and cracked so that ice was showing in small patches over much of the plot. Two days after the start of thaw and 20 days after application, 90 percent of the foam-covered ice was under water and the foam was floating (Figure 3).

In an attempt to achieve a more stable foam coverage, the air content in the foam was reduced, and a 4- to 6-inch layer of foam was applied to 600 square feet of a free-flooded and a confined-flooded plot. Because of the mechanical difficulties already mentioned, these plots were not foamed until thaw. By the time foaming was completed, the plots and much of the surrounding area were slushy or under water. Within 5 days after placement, the surface of the foam on the new plots was covered with cracks. Even so, the protected area was about 5 inches above the surrounding ice surface. As the surrounding ice melted, it was observed that the exposed sides of the foam-protected ice were also melting. After 16 days, although the foam-protected areas were about 18 inches above the surrounding ice surface, only 1/4 of the original protected area was intact, the foam was cracked, and the ice was exposed (Figure 4).

Figure 3. Foam on natural ice floating on water at Point Barrow.

Figure 4. Foam-protected area after 16 days at Point Barrow.

During the Point Barrow trials, the surface of the foam did not cure and dry as it had during laboratory cold-chamber tests. This was attributed to the high relative humidity encountered in the coastal environment. These trials indicated the potential benefit of insulation for protecting ice surfaces, although the protection provided by the CMC-7LP-stabilized foam was short-lived after thaw.

To test the stronger but more viscous CMC-7HP-stabilized foam, NCEL developed a batch generator. The CMC-7HP foam and generator were tested on the beach at Port Hueneme, California.[5] This site closely approximates the higher relative humidity at Point Barrow and the higher solar radiation which prevailed during the Onondaga laboratory tests. The low relative humidity and high solar radiation of the laboratory tests are a rare combination in the ice and snow areas of polar regions. It was recognized that there were certain limitations to this Port Hueneme site since the firm sand base did not simulate the moist cold ice base of earlier tests. To counteract the dryness of the sand, to simulate the wetness of the ice, and to minimize the tendency to draw moisture from the foam, the site was thoroughly wet down before the foam was applied. It was considered that these limitations were overshadowed by the high solar radiation needed for setting up the foam, which was never achieved at Point Barrow.

At Port Hueneme, nine 10- by 10-foot areas were foamed on beach sand above the high-tide line. As the foam aged and dried, it began to crack, apparently from shrinkage, because it also decreased in thickness. According to the Onondaga laboratory tests, the foam should have decreased only slightly in thickness as it dried completely into a cellular consistency. By the time the foam had completely dried, it had pulled together into tufts, and approximately 75 percent of the sand was exposed (Figure 5). Because of the advanced deterioration of the foam, observations were terminated 8 days after the plots were completed.

Traffic tests were begun 4 hours after generation while the foam was still wet. A 1-1/2-ton truck was driven forward over the foam and then backed up at a maximum speed of 5 mph. When the tires rolled over the foam, it stuck until the tires were covered. Where the foam was quite wet and several inches thick, adjacent foam would flow in to fill the tire tracks (Figure 6). As the foam dried and the thickness decreased, it continued to stick to the tire, but less and less would flow into the tracks. When the foam was completely dried, it was merely crushed under the tires.

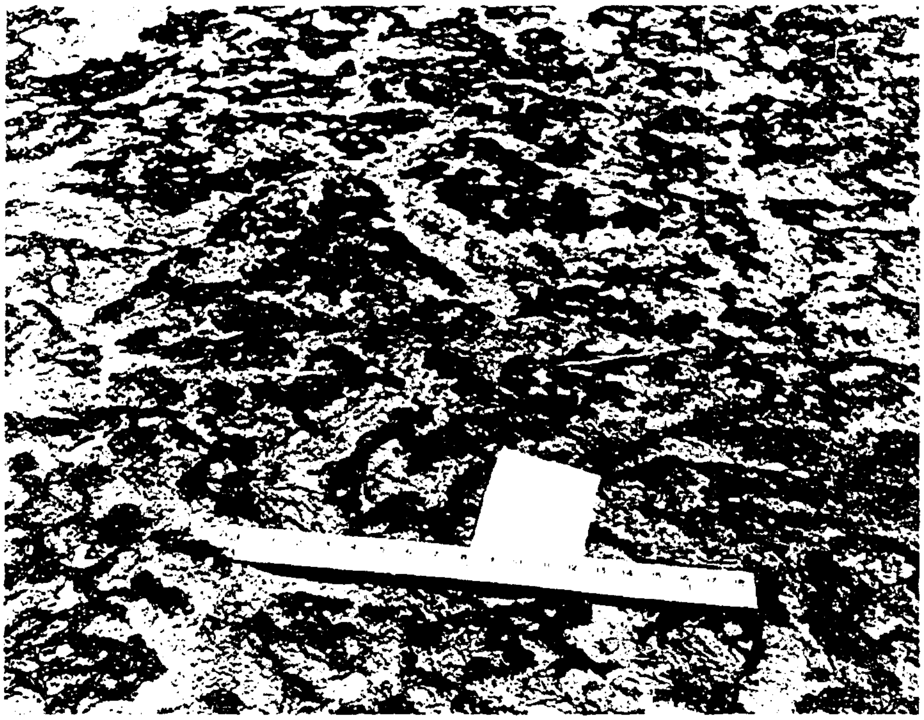

Figure 5. Dried foam on sand at Port Hueneme, California.

Figure 6. Trafficking 4-hour-old foam at Port Hueneme, California.

LOGISTICS

Table I compares the estimated procurement cost and weight of the aqueous foam with those of sawdust. The thickness required for protection is based on field tests.[1,3] The aqueous foam requires a thickness 16 times that of the sawdust because of shrinkage, even though its specific thermal conductivity (k) is only 2-1/2 times more than the sawdust. The CMC-7HP and aluminum acetate stabilizer constitute 23 percent of the weight and 32 percent of the cost; the liquid foam constitutes the remainder. The weight and cost are based on the requirements for a 10,000-foot runway, 200 feet wide, and an expansion ratio of 10:1 for the aqueous foam. These estimates are for one application of the protective covering; however, as the aqueous foam has a poor lasting ability and cannot be trafficked, it would require repeated applications for continuous protection.

Table I. Estimated Cost and Weight Comparison of Sawdust and Aqueous Foam for a 10,000-foot Runway, 200 Feet Wide

Material	k value (Btu/hr/ft/°F/in.)	Thickness (in.)	Cost/lb (c)	Cost/ft^2 (c)	Weight (tons)	Total Cost ($)
CMC-7HP-Stabilized Foam	1.08	4	38.0	7.1	187.2	142,300
Sawdust	0.41	1/4	20.3	4.2	220.0	89,300

FINDINGS

1. Neither the Onondaga laboratory model generator nor the NCEL batch generator were adequate to foam the stronger, more viscous CMC-7HP-stabilized foam.

2. Curing of the foam is strongly dependent upon low relative humidity and high solar radiation — a rare combination in the ice and snow areas of polar regions.

3. The foam has a short field life and cannot be trafficked without damage.

4. Based on one application, for shipment the aqueous foam weighs 15 percent less than sawdust but costs 37 percent more.

CONCLUSIONS

1. Aqueous foam stabilized with CMC is not adequate for continued protection of ice and snow surfaces against summer deterioration.

2. Investigations should continue toward developing a covering for operational areas of ice and snow which protects against deterioration from high solar radiation and near-thawing temperatures.

ACKNOWLEDGMENT

Dr. C. W. Terry designed the NCEL batch generator.

REFERENCES

1. U. S. Naval Civil Engineering Laboratory. Technical Report R-111: Snow compaction equipment — Sprayers and dusters, by E. H. Moser, Jr. and S. E. Gifford. Port Hueneme, Calif., 27 July 1962.

2. Onondaga Associates, Inc. Report OA-R2-FR 63061: Development of foam insulation for protection of arctic airfields, by A. R. Aidun, C. S. Grove, Jr., and K. W. Woodcock. Syracuse, N. Y., August 1961.

3. Onondaga Associates, Inc. Report OA-R4-FR 110162: Development of insulating aqueous foams for protection of ice surfaces by F. C. Shibel, C. S. Grove, Jr., and A. R. Aidun. Syracuse, N. Y., November 1962.

4. U. S. Naval Civil Engineering Laboratory. Technical Note N-477: Protective coverings for sea ice, by N. S. Stehie. Port Hueneme, Calif., December 1962.

5. U. S. Naval Civil Engineering Laboratory. Technical Note N-566: Generation and tests on aqueous foam stabilized with CMC-7HP, by N. S. Stehle. Port Hueneme, Calif., December 1963.

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Key Words: polar construction; aqueous foam; ice and snow deterioration; protective coverings

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